Aus dem Institut für
Medizinische Psychologie
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Direktor: Prof. Dr. H.-J. Steingrüber

PHYSICAL AND NON-PHYSICAL DETERMINANTS OF THE OPERANT EFFECT OF THE DISTRESS VOCALIZATION OF A NEW-BORN CHILD

DISSERTATION
zur Erlangung des Grades
eines Doktors der Medizin
der Medizinischen Fakultät
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vorgelegt von
MARTINA OLTMANN
CHRISTINE WENK
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Physical and Non-Physical Determinants of the Operant Effect of the Distress Vocalization of a New-born Child

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Summary

The negative reinforcing effect of three physical variables (fundamental frequency, intonation, spectral complexity) of a neonate's distress cry and of two different instruction conditions are examined in a 4-factorial analysis of variance design. Using computer analysis and a sampling-rate conversion technique the fundamental frequency of the signal was graded in seven steps. Intonation and spectral complexity was varied in two steps each. The subjects (N = 164) were allowed to control the sound pressure level (SPL-range: 45 db(A) - 95 db(A) by continuously pressing a button in an operant titration situation. The statistical analysis revealed a main effect for the fundamental frequency variable, showing a monotonous decrease of SPL as a function of frequency. A main effect for the intonation variable indicates a preference of the subjects for the intonated vs. monotonous version of the test cry. This preference is most pronounciated in the medium area of the fundamental frequency scale. An effect of the instruction variable is given in combination with the intonation and the complexity variable: The subjects are susceptible to induced motivational influences when certain prerequisites on the side of the physical features are given.

Introduction

The infant's distress vocalization is described as a signal that is appropriate to influence effectfully the behaviour of a caregiving person. Various parameters of the cry-signal - such as timbre, pitch, intonation, loudness, rhythmic patterns, voiced vs unvoiced components, latencies - can be expressed in a very differentiated manner and offer the child numerous possibilities to draw the attention of its caregiving environment to himself and his necessities. Considering these well known phenomena surprisingly little experimental studies are available investigating the relations between physical characteristics of the cry signal and the responses of the receivers of those signals (see Murray, 1979, for a review). The published studies mainly deal with the scaling of attitudes towards different cries by parents and non-parents and/or with the registration of physiological variables (Boukydis & Burgess, 1982; Donovan, Leavitt & Balling, 1978; Frodi & Lamp, 1978; Frodi, Lamp, Leavitt & Donavan, 1978; Frodi, Lamp, Leavitt, Donovan, Neff & Sherry, 1978; Lounsbury & Bates, 1982; Zeskind, 1980; Zeskind & Lester, 1978). Furthermore no experimental attempts have been made to analyse the effects of crying in the sense of instrumentally orientated psychoacoustic

studies. In contrast to subjective scalings and physiological measures, instrumental measures have the advantage of being filled more easily into a learning-theoretical context that is well examined within psycholog In a series of experiments that were carried out at our institute to study the reinforcing properties of acoustic stimuli having both a biological and an artificial origin (Dahmen, Note 1; Meyer, Note 2; Schuessler, Note 3) we used a computer controlled version of the operant titration-technique (Weiss & Laties, 1970). Molino (1973, 1974a, 1974b) used this technique to determine aversion thresholds towards sine-sounds and noise bands. Our results showed that this behavioral technique is a reliable and sensitive method to pursue studies concerning acoustic reinforcement. Meyer (Note 2) already studied pitch and spectral complexity in his experiment. He used, however, artificial, stationary stimuli. His results showed that when rising the frequency the aversion to the stimuli increases. As to the different levels of complexity, he could not prove any differential effects.

Undoubtedly the physical structure of the cry signal has to be looked upon as an important source of

differential effects. Since the early forties it has been the aim of a series of studies to analyse and classify this structure. In particular the group of the Finnish pediatrician Wasz-Hoeckert (Wasz-Hoeckert, Lind, Vuorenkoski, Partanen & Valanne, 1968) has been trying to make a catalogue of different characteristics of the newborn vocalisation, using sound-spectrography, and to use this catalogue for diagnostic purposes. The infant's cry shows typical characteristics with respect to the pitch and intonation of the signal (corresponding to the level and temporal variation of the fundamental frequency) that can even be of diagnostic relevance for the newborn's neurological state of risk. The cries of mentally sick newborn children or those with chromosomal aberrations or various kinds of obstetric complications often show distinct features with respect to these two parameters as opposed to cries of new-born children without complications (Lind, Wasz-Hoeckert, Vuorenkoski, Partanen, Theorell & Valanne, 1966; Michelsson, 1971; Oswald, Peltzman, Greenberg & Meyer, 1970; Zeskind & Lester, 1978) However, the work of these and of other authors (Oswald, 1968; Truby & Lind, 1965; Wolff, 1969) are limited to the classification of physical

parameters of crying. On the basis of these classifications alone it is not possible to draw any conclusions on the specific behavioral effect of specific physical cry components.

Therefore it was our aim to study the reinforcing effect of the following characteristics of a cry signal:

1. Pitch (fO-level).
2. Intonation (fO-variation).
3. Spectral complexity.

Beyond these three aspects that are motivated by physical characteristics we wanted to reveal whether it is possible to show an effect of the induction of different attitudes towards the experimental stimuli. Thus, Donovan et al. (1978), Frodi & Lamp (1978), Frodi et al. (1978) and Wiesenfeld & Klorman (1978) could show that certain situative factors (e.g. informations about the state of risks of the child, video recordings of smiling versus crying children) have a significant effect on the physiological and subjective responses of the listeners. As crying behavior has an essential communicative function for the child's interaction with its caregiving environment, it can be hypothesized that different attitudes towards these signals influence their reinforcing properties.

Method

As independent variables we used 3 acoustic conditions (fundamental frequency, intonation, complexity) and one non-acoustic condition (instruction). The experiment was carried out as a 4-factor analysis of variance design with repeated measurement of one factor (fundamental frequency). Table 1 shows the plan with the 2x2x2x7=56 cells.

Table 1

Plan of the Experiments with 8 Independant and 7 Dependant Conditions

Instruction	Intonation	Complexity	Fundamental frequency (Hz) 305 458 534 610 686 915 1220
'healthy'	into-nated	1	N = 16
		2	N = 19
	mono-tonous	1	N = 18
		2	N = 18
'sick'	into-nated	1	N = 24
		2	N = 23
	mono-tonous	1	N = 22
		2	N = 24

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The acoustic conditions were realized with the help of a Z-80 laboratory computer system (CP/M compatible modulary ECB-Bus system) equipped with 12 bit analogue-digital and digital-analogue interfaces and a software structure written in Fortran and machine language to meet the requirement of a sampling-rate conversion of the acoustic signal. For the experiment we chose a section of 4,6 sec. duration of a cry which was, based on its powerspectrum, within the standard of a random sample of 27 cries (Nolten et al., Note 3). For spectrum analysis the signal was read into the computer's memory by 12-bit analogue-digital conversion with a sampling rate of 10 kHz. The spectrum was calculated for every time segment, smoothed by a gliding Hamming-window, using an efficient FFT-algorithm (Bergland & Dolan, 1978). In order to vary the level of the f0 and the intonation pattern of the test cry a f0-value was determined every 12.5 msec. by a peak-picking procedure. If no valid measurement could be determined at a given time segment, because the energy level of the signal was too low or unvoiced components were superposing the voiced signal components, the analysing programme started a second course replacing the missing point with the average value of the fundamental frequency.

A segment by segment sampling-rate conversion was performed in order to increase or to decrease the f0-level by a decimation and interpolation procedure (Crochiere, 1979), while keeping the time length of the signal constant. In Fig.1 the result of the analysis is plottet as a function of time, showing both the variation of the frequency and the amplitude of the first harmonic of the test cry.

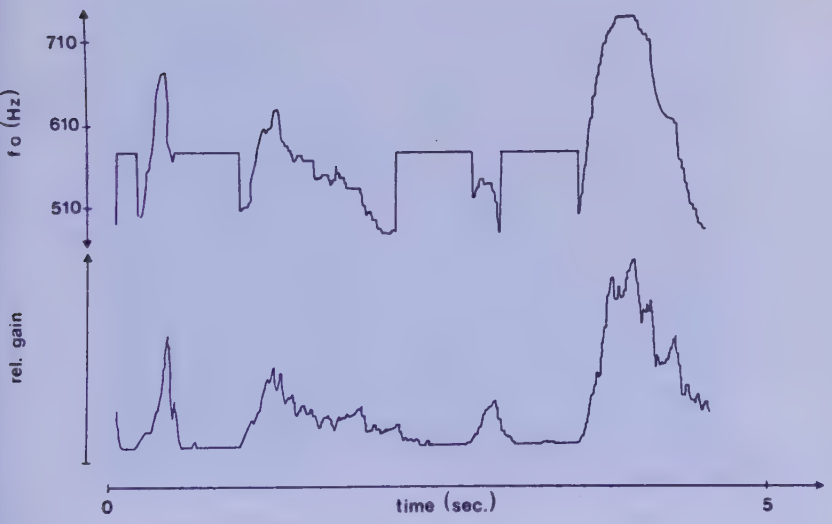

Fig.1: Fundamental frequency (medium value: 610 Hz) and amplitude of the fundamental frequency of the test cry during a period of 4.6 sec.

The different versions of the signals produced by the computer were dubbed repeatedly onto tape (Revox A 700); i.e. for every stimulus condition the signals were repeated every 4,6 sec., till a stimulus sequence of 90 sec. was reached. According to the experimental design 7 different versions of the repeated measurement variable in every experimental session were realized. They were permutated in the order of 1, 2, n, 3, n-1, 4, n-2 etc., making sure that no individual sequence of stimuli was repeated. The stimuli were separated from each other by pauses lasting 15 sec. . Each stimulus was announced by a short standard sentence: "Stimulus no. ... will follow." Fig.2 to 4 show the results of these manipulations in spectral presentation. Because of the chosen form of synthesizing the stimuli, it could be made sure that just one signal parameter at a time was varied and the other ones were kept constant.

Fundamental frequency

The treatment of the frequency condition as a repeated measurement factor with 7 steps was carried out according to Meyer (Note 2). The medium fO-level of the experimental cry was 610 Hz (see Fig.1). In a range of $\pm$ 1 octave all other fO-conditions were varied

in 7 steps. This interval-range was taken for two reasons: a) in order to cover the area of the fundamental frequency of healthy new-born children (ca. 350-650 Hz) and b) in order to produce, with the help of the two highest grades, conditions that can be observed with pathological patterns of cries (Michelsson, 1971).

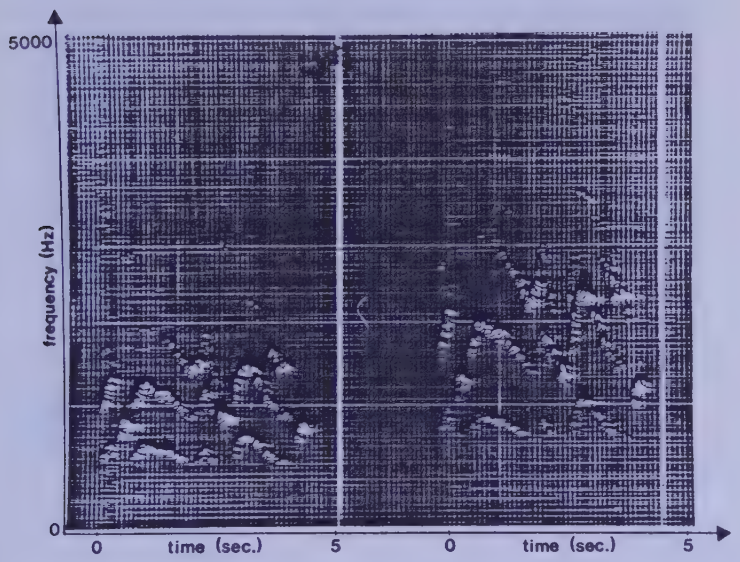

Fig.2: Spectral analysis of the experimental cry signal and of the version lifted up for 1/2 octave.

As an example in Fig.2 the signal's average fundamental frequency on the right side is lifted up for 1/2 octave onto 915 Hz in comparision to the original on the left side.

Intonation

The intonation was varied in 2 versions: intonated versus monotonous. Fig. 3 displays the two stages of the intonation factor.

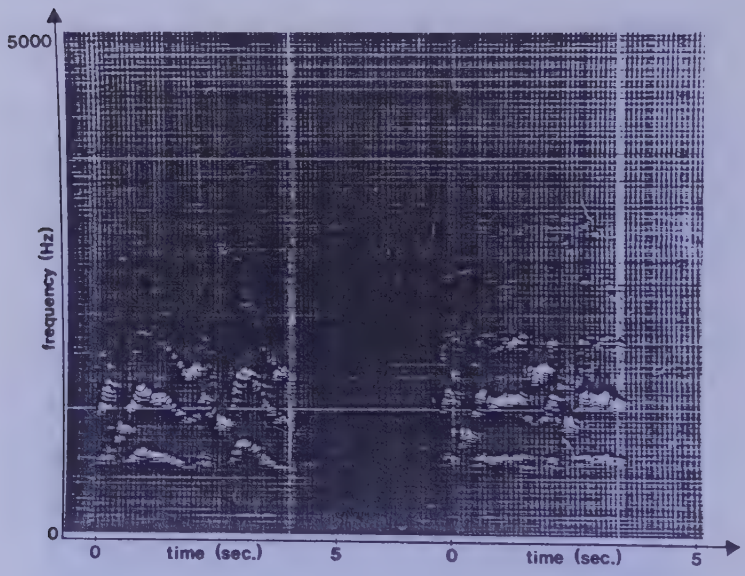

Fig. 3: Spectral analysis of the cry signal (left side) and of the monotonous version (right side).

Spectral complexity

The complexity was varied in 2 steps (see Fig. 4) : The first step corresponds to the original version. The second, elevated grade of complexity was reached by

lifting up the original by 1/2 octave and by adding this elevated version to the original.

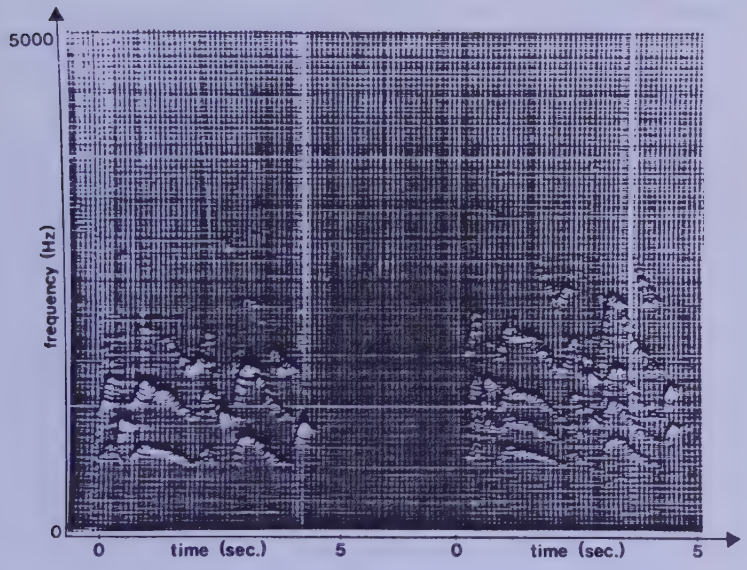

Fig. 4: Spectral analysis of the cry signal (left side) and of the version with the elevated spectral complexity (right side).

Instruction conditions

The subjects were exposed to two different experimental instructions: 1. "These vocalizations are cries of a healthy new-born child." 2. "These vocalizations are cries of a sick new-born child."

Operant technique

The operant titration technique, that was used in the experiment was based on the following reinforcement princi (Dahmen, Note 1; Meyer, Note 2; Schuessler, Note 4): By pushing a button continuously, the subjects could control the level of the second pressure of the stimuli within the limits of a maximal sound pressure level (SPL) of 95 dB(A) and a minimal SPL of 45 dB(A). Fig.5 presents the relation between the operant level and the SPL. This relation descr the transfer function of the system.

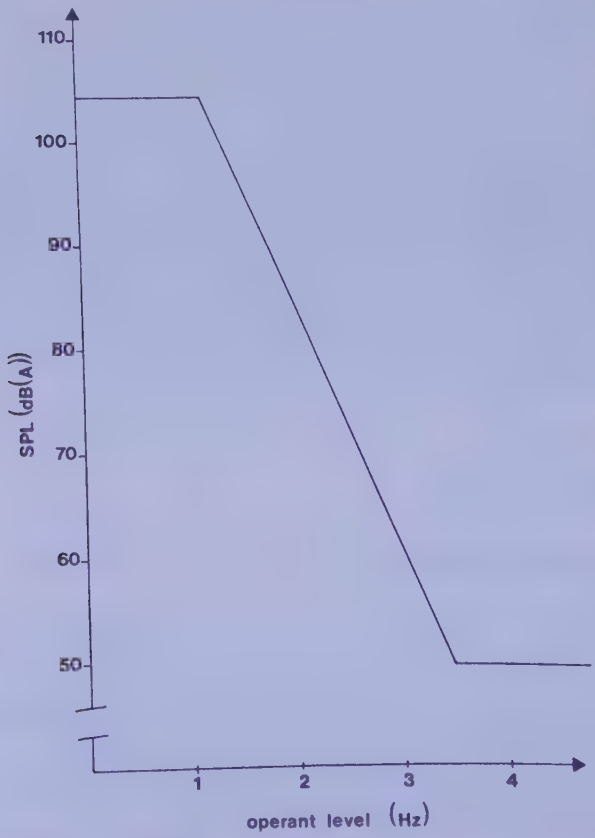

Fig. 5: SPL (in dB(A), measured in the head phone) as a function of the operant level (in Hz).

The pushing of the button was simulated electronically and the SPL in the head phone was determined by a sound level meter equipped with an artificial ear (Bruel and Kjaer 2203, 4152). Fig. 6 presents the schematic plan of the experimental arrangement.

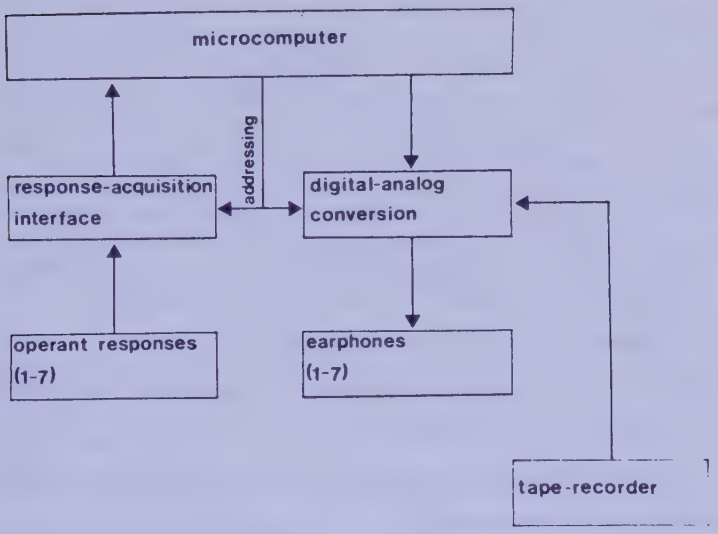

Fig. 6: Scheme of the titration technique

Before storing in the computer, the frequency of the operant responses were transformed in a corresponding voltage by a frequency voltage converter. The different voltage levels were read into a micro computer (Intercept I) through a multichannel analogue-digital converter.

The computer itself, dependant on the input, attenuated a series of voltage-controlled amplifiers with the help of a periphery of digital-analogue converters.

Procedure

The experiment was carried out in a sound-shielded room with seats for the subjects separated from each other by a partition wall. The button that could be used to control the sound intensity when being pushed slightly was installed on the table in front of the seats. The stimuli were presented through head-phones (Pioneer SE-305) that guarantee a sufficient screening from exterior stimuli. At the beginning of each experimental session the experimenter read an instruction which was lying also in front of the test persons in a written form. They were informed that they were taking part in a psycho-acoustical experiment and that they could influence the sound intensity by pushing the button in front of them. They were asked to keep the sound intensity on a level of most comfortable loudness. During a following training-period of 3 minutes the subjects were made familiar with the titration procedure. A pulsation sine-tone of 440 Hz was used as the reinforcing signal. After the training the seven experimental stimuli were presented. The sessions with 4 groups of subjects every day took place during a period of 2 weeks from Mondays to Fridays at a fixed time from 11 a.m. to 2 p.m. .

The subjects were 164 male and female non-parents (2' to 3' semester medical students, mean age: 23.6 years), accomplishing a preclinical course in medical psychology.

Statistical analysis

The evaluation of the data (total amount of operant responses / stimulus sequence) was carried out as a four factorial analysis of variance with repeated measurement on one factor with the programme-package BMDP 2V. On the basis of the analysis of variance, possible interactions were analysed by considering simple effects with the Tukey q-statistic (Kirk, 1968).

Results

The analysis of variance showed a significant main effect, $F(6,888) = 19.82$, $p < .001$, for the fundamental frequency variable (Fig. 7). As for convenience the data are transformed into db(A) by using the transfer function of the operant system (Fig. 5).

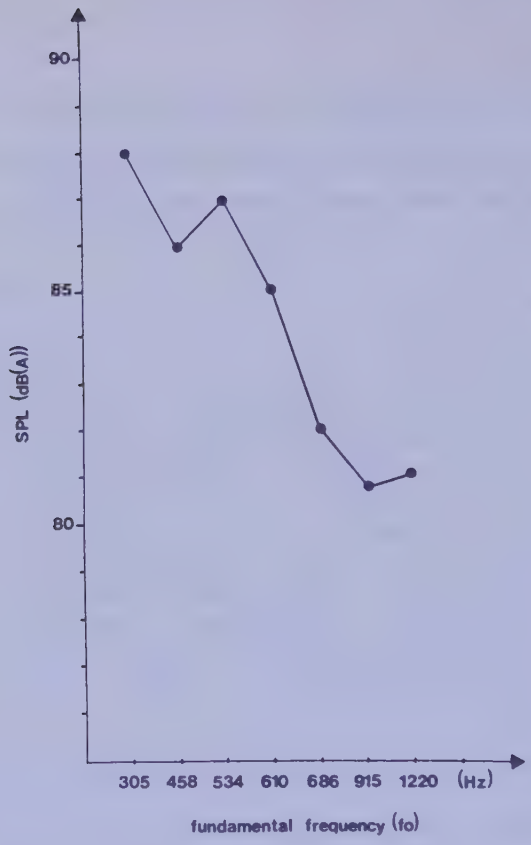

Fig. 7: Sound pressure level for the 7 stages of the fundamental frequency variable.

The first four stages and the last three stages of the fundamental frequency do not differ significantly from each other in their respective SPL's. Between the SPL at 610 Hz and the SPL at 686 Hz, however, a significant difference, $q_{.05,21,\infty} = 3.4$ db(A), $p < .05$, can be observed. All SPL-differences greater than that, for

example between 534 and 915 Hz, were highly significant, q .01,21, ∞ = 3.9 db(A), $p < .01$. The following figure (Fig. 8) presents a significant interaction between the two stages of the complexity variable and the stages of the fundamental frequency variable, $F(6,888) = 9.91$, $p < .001$.

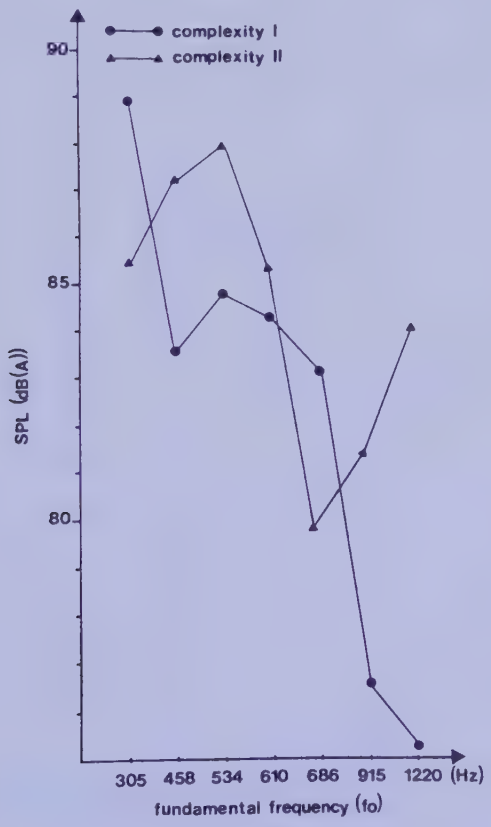

Fig. 8: Sound pressure level for the two stages of the complexity variable dependant on the fundamental frequency.

The interaction obviously is based on the fact that the two stages of complexity differ significantly in their SPL' at 915 Hz, q .05,2, ∞ = 5.2 db(A), $p < .05$, and 1220 Hz, q .01,2, ∞ = 7.6 db(A), $p < .01$, but not at the other sta of the fundamental frequency variable. The next figure (Fig shows a main effect for the two intonation conditions, $F(1,148) = 7.15$, $p < .01$, and an intonation x frequency int action, $F(6,888) = 2.7$, $p < .02$, due to trend difference between the two intonation conditions.

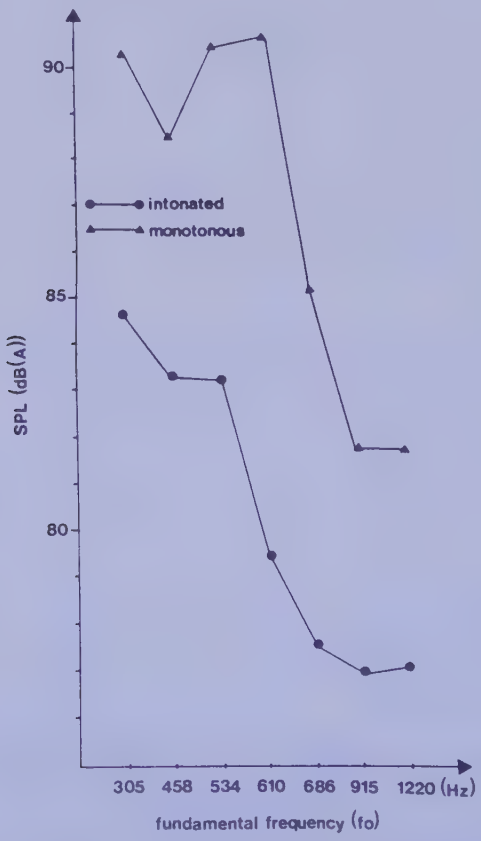

Fig. 9: Sound pressure level for the two intonation conditi in relation to the fundamental frequency.

The intonation main effect obviously depends on a difference in the SPL of the two curves showing a generally higher SPL for the intonated version. The intonation x frequency interaction depends upon trend differences between the two curves. In the medium area of the frequency dimension this difference is most pronounciated. Instead of showing a decline of the SPL, as it can be seen in the monotonous signal version from 534 Hz to 610 Hz, the SPL even ascends a bit in the intonated version. Fig. 10 presents an interaction of the intonation variable with the instruction variable, $F(1,148) = 6.56$, $p < .02$, and the mentioned above main effect for the intonation variable.

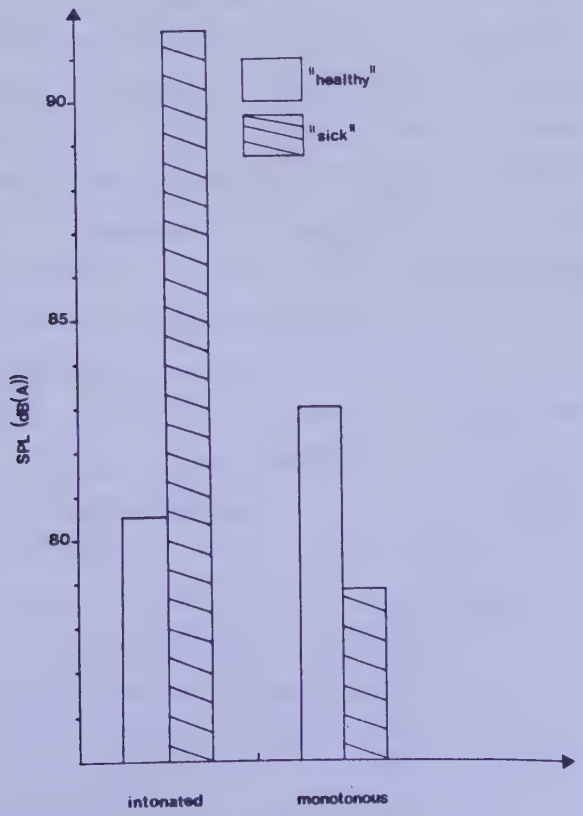

Fig. 10: Sound pressure level for the two stages of the intonation and instruction variable.

In the intonated version with the instruction 'sick' the subjects accept an SPL in the near of the upper limit of 95 dB. With the instruction 'healthy', they accept an SPL of 80.5 dB that diverges clearly, $q_{.05,6,\infty} = 8.4$ db(A), $p < .05$, from the maximal value. The two remaining SPL values that are valid for the monotonous version of the signal, significantly diverge, $q_{.05,6,\infty} = 8.4$ db(A), $p < .05$, from this maximal value, too. In the monotonous version with the instruction 'healthy', the SPL is above the level of the intonated version, whereas the level for the instruction 'sick' lies below that of the intonated version. On this diverging relation the significant interaction effect is based. Fig. 11 presents an interactive tendency between the variables complexity an isntruction, $F(1,148) = 3.45$, $p = .065$.

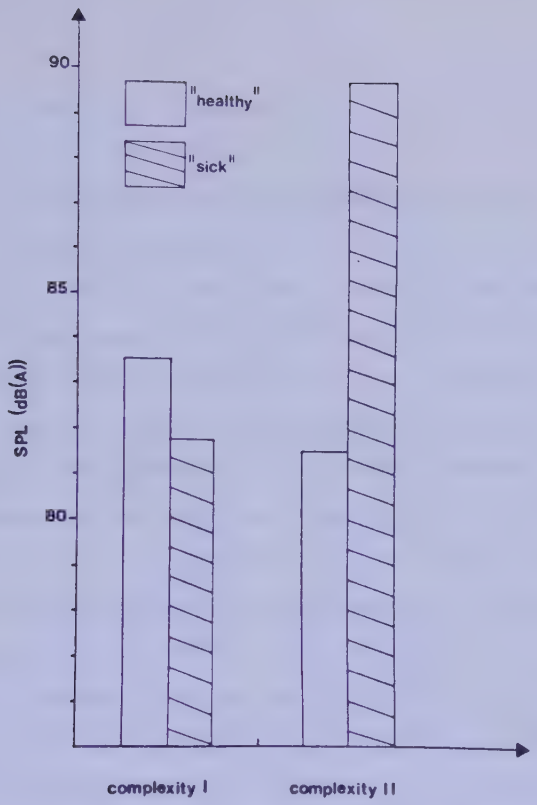

Fig.11: Sound pressure level for the two stages of the factors complexity and instruction.

With respect to the instruction 'healthy', we can recognize a slightly elevated SPL of the complexity condition 'single' in comparision to the twofold complexity version. On the other side, concerning the instruction 'sick', we have a clearly lower SPL, q .05,6, ∞ = 8.1 db(A), p $<$ .05, with single complexity in comparision to the twofold complexity.
The difference between the conditions 'sick' vs. 'healthy' with twofold complexity is significant, too, q .05,6, ∞ =8.1 db(A), p $<$ .05.

Discussion

The experimental manipulation of the signal characteristics and the different instruction conditions led to considerable changes of the operant effects of the signal. As already demonstrated in previous experiments (Dahmen, Note 1; Meyer, Note 2; Schuessler, Note 4), the operant titration technique has been proven to be a sensitive indicator for the reinforcing effects of acoustic signals. The accepted SPL can be interpreted as the expression of an equilibrium between the tendency to escape the aversive acoustic stimulation on the one hand and on the other hand the tendency to keep the motoric effect of pushing the button on a low level. It thus may be seen as a compromise for the subjects when trying to escape two aversive conditions. It can also be defined as an aversive threshold if it is taken into consideration that at the point of equilibrium the aversive stimulation is a minimum. Concerning the physical parameters of the signal, the analysis of variance reveals the existence of main effects (fundamental frequency, intonation) on the one hand and interaction effects (fundamental frequency / complexity, fundamental frequency / intonation) on the other hand.

The fundamental frequency main effect basically means that the SPL accepted by test persons decreases while the fundamental frequency of the signal is rising. Thus the result is in accordance with the frequency effects Meyer (Note 2) could demonstrate for artificial staticnary accoustic signal and Dahmen (Note 1) for cry signals of newborn children. Murray (1979) states that parametric psychophysical research concerning the behavioral effects of physical characteristics of the newborn vocalization is not yet published. Nevertheless there is evidence that high frequency cries as produced by abnormal and high-risk children are perceived as being more aversive than those of control children (Frodi et al. 1978). Zeskind and Lester (1978) found that the distress-cries of newborn children with pre- and perinatal complications (fO = 814 Hz) are rated as being more "aversive" and "stressing" than the cries of healthy new-born children (fO = 468 Hz). Molino (1974 a,b) and Meyer (Note 2) show, that there is a coherence between frequency dependant loudness on one side (Fletcher & Munson, 1933) and frequency dependant operant escape behavior on the other side. Thus it is possible to describe the fundamental frequency effect within a framework of other frequency related psycho-acoustic results.

Concerning the remaining results of the experiment, an anchoring into literature is not yet possible because the questions formulated in this paper have, as far as we see, not yet been dealt with experimentally in this way. The main effect of the intonation means that the monotonous version of the test cry is accepted by the subjects to a remarkably lower degree than the intonated version. Physically spoken, the two versions differ from each other in the fact that the monotonous version has no variation of the fundamental frequency and thus the remaining harmonics do not vary in frequency either. Psychologically spoken, there is no variation in pitch or - in musical terms - the voice has no melody any longer. It is known that simulated emotional states can affect both the level and the variability of the fundamental frequency of the human voice (Williams & Stevens, 1972). If the variability of the f0 is limited, consequently an important part of the emotional expression of the vocal signal is restricted. The lack of expression of the monotonous version, that is produced artificially, obviously leads to a greater aversive effect of the signal. Considering the interaction intonation x frequency the difference between the two intonation conditions is particularly high in the medium area of the frequency-dimension. This effect may be interpreted as showing a tendency of the subjects to

differentiate more sensible in a frequency area, where the normal value of the fO of a newborn vocalization is to be expected. The dimension complexity in combination with the fO-dimension is differentially effective, too. The fO at 915 and 1220 Hz can be accepted more easily at stage II of the complexity than at stage I. In other words: If a generally existing aversive effect of higher fO conditions is presumed, stage II of the complexity obviously moderates this aversive effect. A further effect of moderation at stage II of the complexity in relation to the instruction 'sick' can be observed: If these conditions appear in combination, the subjects tolerate a significantly higher SPL than with the combination stage II of the complexity instruction 'healthy'.

The interaction of the intonation variable with the instruction variable is quite puzzling. The intonated version of the test cry in combination with the instruction 'sick' is tolerated at the almost highest possible value of the SPL-scale. All other instruction / intonation combinations differ significantly from this value. Its monotonous counterpart in combination with the same instruction even is titrated to a SPL-level below 80 db(A). As there is a dominant effect of the intonation variable in the data (intonation main effect) it can be speculated that the influence of the

instruction variable is of second order. A hypothetical motivational process, induced by the instruction, may thus need certain physical prerequisites to be observable. However, a systematical analysis of the relative weight of the two types of variables involved (physical vs. motivational) needs further experimental exploration to be fully understood. From the results of other groups (Donovan et al., 1978); Frodi & Lamp, 1978); Frodi et al., 1978; Wiesenfeld & Klorman, 1978) we know that the induction of different attitudes - e.g. by presenting different video recordings - can produce different responses towards the acoustic signals of babies. But in this case as well, it is unclear in which way the various factors are related to each other. The interactive instruction effects pobably is related to a broader context of motivational variables and emotional dispositions influencing the receptive behavior of the listener. If, for example, parents instead of non-parents would have been used as subjects, the observed instruction effects may quite possible have been of different shape. Zeskind (1980) reports that parents differed from non-parents in their response patterns to pain cries of newborns using a questionnaire as dependant variable. An experimental test of this kind of interaction would be to compare parents with non-parents in combination with various instruction conditions in their titration behavior.

However, a causal analysis of the participating variables at first demands - as a prerequisite of broader conceptualizations - a profound description and analysis of the physical signal parameters in terms of behavioral effects.

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